

1  
JC20 Rec'd PCT/PTO 12 JUL 2003

## DESCRIPTION

## DISPLAY APPARATUS

## 5 TECHNICAL FIELD

The present invention relates to a moving particle type display apparatus which performs a display based on charged particles which move when a voltage is applied thereto.

10

## BACKGROUND ART

Development and research into moving particle type display apparatuses which perform a display based on charged particles which move when a voltage is applied thereto is being carried forward vigorously in recent years, and great attention is focused above all on an electrophoresis display apparatus.

This type of electrophoresis display apparatus is provided with a back substrate and a front substrate arranged with a predetermined gap in between and an insulating liquid and charged particles are placed in the gap between these substrates. Furthermore, each pixel is provided with a first electrode having a large display area and a second electrode having a small display area on one substrate (back substrate). For example, when a

monochrome display is performed, a color difference is used for a display as follows:

(1) When charged particles are attracted to the first electrode and scattered over a wide area, the first  
5 electrode is covered with the charged particles, and therefore the color (e.g., black) of the charged particles is visible to an observer.

(2) When charged particles are attracted to the second electrode and concentrated in a narrow area,  
10 the color (e.g., white) of the area where the first electrode is formed is visible to the observer.

There is also a proposal on a display apparatus constructed in such a way that a shielding layer is placed to hide the second electrode and charged  
15 particles attracted by the second electrode are not visible to the observer (Japanese Patent Application Laid-Open No. H09-211499).

However, the above described electrophoresis display apparatus has problems yet to be solved in  
20 aspects of display quality. This seems to be attributable to the following two factors:

First, in the case (1) above, it is desirable that charged particles be scattered over the entire first electrode at substantially the same density and  
25 the first electrode be hidden behind the charged particles. However, in reality, the density of the charged particles is reduced in areas adjacent to the

second electrode and the "color of the base (that is, the color of the area where the first electrode is formed)" is reflected and made visible. For this reason, the display quality deteriorates. The  
5 reasons for such a phenomenon are not clearly defined but there are a few possible reasons as follows:

- 1) Since the second electrode has the same polarity as that of the charged particles, an electrostatic repulsive force may be generated between the second  
10 electrode and charged particles.
- 2) When a barrier is placed so as to separate a pixel, this causes the "area where the second electrode is formed" and areas adjacent thereto not to become level but inclined and as a result, the charged  
15 particles may be hardly at rest.

#### DISCLOSURE OF THE INVENTION

The present invention has been implemented in view of the above described circumstances and it is  
20 an object of the present invention to provide a reflective display apparatus which creates a display by moving particles, comprising a front substrate and a back substrate, a plurality of charged particles sandwiched between the front substrate and back  
25 substrate, a first electrode and a second electrode placed on the back substrate, a support member provided to keep a distance between the front

substrate and the back substrate and a colored area on the back substrate, characterized in that reflecting means is provided in the space partitioned by the support member and the colored area is placed  
5 in such a way that the surface of projection on the back substrate of the second electrode and the surface of projection on the back substrate of the colored zone at least contact with each other.

#### 10 BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A and 1B are cross-sectional views showing an example of a structure of an electrophoresis display apparatus according to the present invention;

15 Fig. 2 is a cross-sectional view showing another example of the structure of the electrophoresis display apparatus according to the present invention;

20 Fig. 3 is a cross-sectional view showing a further example of the structure of the electrophoresis display apparatus according to the present invention;

Figs. 4A and 4B are cross-sectional views showing a still further example of the structure of  
25 the electrophoresis display apparatus according to the present invention;

Figs. 5A and 5B are cross-sectional views

showing a still further example of the structure of the electrophoresis display apparatus according to the present invention; and

5 Fig. 6 is a cross-sectional view showing a still further example of the structure of the electrophoresis display apparatus according to the present invention.

10 Fig. 7 is a cross-sectional view showing a still further example of the structure of the electrophoresis display apparatus according to the present invention.

#### BEST MODE FOR CARRYING OUT THE INVENTION

15 For the purpose of explaining embodiments of the present invention, the following terms, etc., will be defined. The color of the surfaces of charged particles is defined as a "first color." The range in which charged particles can exist is defined as one "pixel." When the area of a portion involving  
20 the display performance of the apparatus is discussed, this area is defined as the area of an image obtained by vertically projecting the portion onto a plane parallel to the substrate. When this should be specifically clarified, a term "projected area" is  
25 used.

With reference now to Figs. 1A and 1B to Fig. 3, an embodiment of the present invention will be

explained below.

An electrophoresis display apparatus according to this embodiment includes a back substrate 1 and a front substrate 2 and an insulating liquid 8 and a plurality of charged particles 9 are placed between the substrates 1 and 2. For each pixel A, a first electrode 3 and a second electrode 4 are placed. The first electrode is placed along the back substrate in a relatively wide area (hereinafter referred to as "first electrode area")  $A_1$  and the second electrode is placed in a relatively narrow area (hereinafter referred to as "second electrode area")  $A_2$ . When both the first electrode area and the second electrode area border each other on a boundary, a colored area  $A_3$  colored in substantially the same color as the first color is made up of both areas adjacent to the boundary and when the first electrode area and the second electrode area do not directly border each other and there is an area between the two areas (hereinafter referred to as "intermediate area"), the colored area  $A_3$  is made up of the intermediate area and areas adjacent to the intermediate area. Therefore, when the width of the second electrode between the first electrode areas is small, the entire second electrode area may be included in the colored area as shown in Fig. 1A, Fig. 1B, Fig. 2 and Fig. 3. The first electrode area except the colored

area is colored in a different color (hereinafter referred to as "second color"). The colored area  $A_3$  is preferably strip-shaped along the boundary between the first electrode and second electrode.

5           When the colored area  $A_3$  is too wide, the part displaying the second color, that is, the proportion of the part of the first electrode area  $A_1$  other than the colored area is reduced, causing visibility to be reduced when the second color is displayed. On the  
10           contrary, when the colored area  $A_3$  is too narrow, the same problem as that of the conventional art occurs, that is, when the first color is displayed, loss of color may occur. The area of the colored area  $A_3$  needs to be decided taking all these problems into  
15           consideration. More specifically, it is necessary to design the area and shape of the colored area  $A_3$  taking into account an area C (hereinafter referred to as "particle hiding area") of the first electrode area hidden behind charged particles when the charged  
20           particles are concentrated in the vicinity of the second electrode and an area E where the first electrode area is exposed because of an insufficient density of the charged particles (hereinafter referred to as "exposed area of the first area") when  
25           the charged particles are moved onto the first electrode.

(First embodiment)

With reference to Figs. 1A and 1B to Fig. 3, a first embodiment of the present invention will be explained below.

It is possible to place a support member 6  
5 between substrates 1 and 2 so as to partition a pixel.  
In that case, a second electrode 4 may be placed:  
(1) between the support member 6 and a back substrate  
1 as shown in Fig. 1A and Fig. 2,  
(2) on the side of the support member 6 as shown in  
10 Fig. 1B or  
(3) at a position other than the position at which  
the support member 6 is placed as shown in Fig. 3.

In order to calculate the particle hiding area  
in the modes (1) to (3), it is possible to calculate  
15 the projected area of the group of charged particles  
concentrated in the vicinity of the second electrode  
from the pixel shape and diameter of charged  
particles and calculate the projected area based on  
this calculation result. When charged particles 9  
20 cannot be accumulated on the surface of the second  
electrode 4 parallel to the back substrate as in the  
cases of the mode (1) in Fig. 1A and Fig. 2 above and  
the mode (2) in Fig. 1B, it is possible to calculate  
the particle hiding area from the projected area of  
25 the group of charged particles concentrated in the  
vicinity of the second electrode. When the charged  
particles 9 can be accumulated on the surface of the



second electrode 4 parallel to the back substrate as in the case of the mode (3) above in Fig. 3, it is possible to calculate the particle hiding area by subtracting the area of the second electrode area on which charged particles are placed from the projected area of the group of charged particles concentrated in the vicinity of the second electrode.

In order to decide the value of the particle hiding area and the shape more accurately, it is possible to carry out a field intensity simulation and decide the particle hiding area and the shape along an equipotential line when a voltage of the same polarity as that of charged particles is applied to the first electrode 3 or based on the result of an optical observation when charged particles are concentrated around the second electrode.

With regard to the value of the exposed area of the first area and the shape, it is possible to carry out a field intensity simulation and decide the exposed area of the first area and the shape along an equipotential line when a voltage of the polarity opposite to that of charged particles is applied to the first electrode 3. Or it is also possible to decide the exposed area of the first area and the shape based on the result of an optical observation when particles are moved onto the first electrode and calculate the exposed area of the first area and the

shape according to the actual situation.

When the particle hiding area including the shape exceeds the exposed area of the first area, it is preferable to define the intermediate area and shape for the colored area  $A_3$ . In that case, the colored area  $A_3$  need not necessarily cover the entire width of accumulated charged particles.

On the other hand, when the particle hiding area is smaller than the exposed area of the first area, it is necessary to decide the area of the colored area and the shape according to the priority level of light and shade, but from the standpoint of a pixel aperture ratio, it is desirable to set the area and the shape of the colored area to the particle hiding area or smaller.

A display is performed by applying a voltage between the second electrode 3 and first electrode 3 and thereby moving charged particles 9 between the two electrodes. For example, when the charged particles 9 are attracted to the first electrode 3 and placed so as to cover the first electrode 3, the first color of the charged particles 9 is visually recognized as the color of the pixel. On the other hand, when the charged particles 9 are attracted to the second electrode 4, the first electrode area  $A_1$  is exposed and the second color is visually recognized as the color of the pixel.

Note that there are various methods for coloring the first electrode area  $A_1$  such as a method of coloring the first electrode itself, a method of providing a colored layer in addition to the  
5 electrode and a method of coloring an insulating layer placed so as to cover the first electrode.

Furthermore, as the method of coloring the colored area  $A_3$ , a method of placing a colored layer (see reference numeral 8 in Figs. 1A and 1B) colored  
10 in substantially the same color as the first color is available. As the method of forming such a colored layer, a method of applying a photosensitive resin layer mixed with pigment and dye, then carrying out exposure and wet developing or a method of forming  
15 the colored layer using a printing method is available.

Hereinafter, components of the electrophoresis display apparatus will be explained.

It is preferable to place the support member 6  
20 in the gap between substrates so as to partition one pixel from another. It is possible to use polymer resin as this support member 6 and more specifically, it is possible to use polyimide resin, polyester resin, polyacrylate resin, polymethacrylate resin,  
25 polycarbonate resin, polyallylate resin, novolac resin, epoxy resin, etc., as this support member 6. Examples of the method of forming this support member

6 include:

- Method of applying a photosensitive resin layer, then carrying out exposure and wet developing
- Method of forming support member 6 using a printing method
- Method of forming a barrier and then adhering it to the substrate
- Method of forming support member 6 on an optically transparent substrate surface through molding

10           For the substrate 1 and 2, it is possible to use a polymer film such as polyethylene terephthalate (PET), polyether sulfone (PES), polyimide (PI) and polyethylene naphthalate (PEN), polycarbonate (PC), an inorganic material such as glass and quartz or a  
15           stainless steel substrate, the surface of which includes an insulating layer. Note that for the substrate 2 on the observer side, it is possible to use a material with high transmittance of visible light such as a transparent polymer film and glass.  
20           Furthermore, it is also possible to form a resin layer (see reference numeral 42) made of a polymer material whose rubber hardness is within a range of 10 to 90, or more specifically silicon resin, natural rubber, thermoplastic elastomer resin on the surface  
25           of the substrate 2 (surface contacting the insulating liquid 8).

          Furthermore, it is possible to use any material

for the electrodes 1 and 2 if it is at least a  
conductive material that can be patterned, for  
example, indium tin oxide (ITO), aluminum and  
titanium. Note that in the electrophoresis display  
5 apparatus shown in Figs. 1A and 1B, the first  
electrode 3 and second electrode 4 are formed at  
different heights (that is, a position offset with  
respect to the direction normal to the substrate),  
but they can also be formed at the same height.  
10 Furthermore, in the electrophoresis display apparatus  
shown in Figs. 1A and 1B, the first electrodes 3 of  
different pixels are separated from one another and  
there is no electrical continuity among them, but it  
is also possible to provide electrical continuity  
15 among the first electrodes 3 of different pixels.

It is preferable to form an insulating layer on  
the surfaces of these electrodes to

- insulate one electrode from another or
- prevent injection of charges from electrode to

20 charged particles 9.

As a material used for this insulating layer,  
it is preferable to use a thin film in which pinholes  
are hardly formed. More specifically, polyimide  
resin, polyester resin, polyacrylate resin,  
25 polymethacrylate resin, polycarbonate resin, etc.,  
having high transparency can be used.

Furthermore, it is also possible to:

- place a scattering layer in front of the first electrode 3 (upper part in the figure) (see reference numeral 10) or
- make the first electrode 3 transparent and place a reflecting layer behind (lower part in the figure) (not shown).

As the scattering layer, it is possible to use a transparent insulating layer containing highly reflective micro particles and it is preferable to use titanium oxide or  $\text{Al}_2\text{O}_3$  as micro particles and acrylic resin, urethane resin, fluorine-based resin, norbornene resin, PC, PET, etc., can be used as the insulating resin. When the scattering layer is thick, it is possible to increase the reflective factor and improve the display quality, but on the contrary it is possible to cause the drive voltage to rise. Therefore, the thickness of the scattering layer is preferably within a range of 0.1 to 20  $\mu\text{m}$ .

An average particle diameter of charged particles 9 used in the present invention is preferably within a range of 0.1  $\mu\text{m}$  or above and 10  $\mu\text{m}$  or below. The coloring agent is not particularly limited, but it can be, for example, carbon black, titanium oxide, barium sulfate, nigrosine, iron black, aniline blue, calcoil blue, chrome yellow, ultramarine blue, Du Pont oil red, quinoline yellow, methylene blue chloride, phthalocyanine blue,

phthalocyanine green, sky blue, rhodamine lake, etc.  
Furthermore, as particle resin, polystyrene,  
polyethylene, polyester, polymethacrylate,  
polyacrylate, polyacrylic ester, polyethylene-based  
5 resin such as polyethylene-acrylic acid copolymer,  
polyethylene-methacrylic acid copolymer,  
polyethylene-vinyl acetate copolymer, other polymer  
material such as polyvinyl chloride resin,  
nitrocellulose, phenol resin, and polyamide resin can  
10 be used. These materials can be used singly or with  
two or more types combined.

As the insulating liquid 8, it is preferable to  
use a low-conductive, high-insulating organic solvent.  
Such a solvent can be aromatic hydrocarbon-based  
15 solvent such as benzene, toluene and xylene,  
aliphatic hydrocarbon-based solvent such as hexane,  
cyclohexane, paraffin-based hydrocarbon solvent,  
isoparaffin-based hydrocarbon and naphthene-based  
hydrocarbon, hydrocarbon halide-based solvent or  
20 silicon oil, high purity petroleum, etc., but above  
all, aliphatic hydrocarbon solvent is preferably used  
and more specifically, isopar-G, H, M, L  
(manufactured by Exxon Chemical), Shellsol (Showa  
Shell Japan), IP Solvent 1016, 1620, 2028, 2835  
25 (Idemitsu Petrochemical), etc., can be used. These  
can be used singly or with two or more types combined.

The insulating liquid 8 may also contain

additives such as charge control agent, dissociation stabilizer, scattering stabilizer for the purposes of increasing the amount of charge of charged particles or providing charge stability.

5           As the charge control agent, it is preferable to use metallic soap and more specifically, metallic soap such as cobalt naphthenate, zirconium naphthenate, copper naphthenate, iron naphthenate, lead naphthenate, manganese naphthenate, zinc  
10 naphthenate, cobalt octanate, zirconium octanate, iron octanate, lead octanate, nickel octanate, manganese octanate and zinc octanate can be used but the charge control agent is not limited to them.

          Furthermore, rosin ester or rosin derivative  
15 can be used for the purposes of increasing the amount of charge of charged particles or providing charge stability. Rosin ester or rosin derivative is not particularly limited as far as it is soluble to the insulating liquid, but can be, for example, gum rosin,  
20 wood rosin, tallol rosin, rosin denatured maleic acid, rosin denatured pentaerythritol, rosin glycerin ester, partially hydrogen added rosin methyl ester, partially hydrogen added rosin glycerin ester, partially hydrogen added rosin triethylene glycol  
25 ester, fully hydrogen added rosin pentaerythritol ester, maleic acid denatured rosin ester, fumaric acid denatured rosin ester, acrylic acid denatured



rosin ester, maleic acid denatured rosin  
pentaerythritol ester, fumaric acid denatured rosin  
pentaerythritol ester, acrylic acid denatured rosin  
glycerin ester, maleic acid denatured rosin glycerin  
5 ester, fumaric acid denatured rosin glycerin ester  
and acrylic acid denatured rosin glycerin ester.

Specific examples of the scattering stabilizer  
include polybutadiene, polyisoprene, polyisobutylene,  
polybutene, styrene butadiene copolymer, styrene  
10 isoprene copolymer, styrene maleic anhydride  
copolymer, norbornene resin and polyethylene wax.  
Above all, styrene butadiene copolymer is preferable,  
for example, as commercially available materials, E-  
SBR, S-SBR (manufactured by JSR Corporation), NIPOL  
15 1502, NIPOL 1712, NIPOL NS112, NIPOL NS116, NIPOL  
1006, NIPOL 1009 (manufactured by Zeon Corporation),  
TAFDENE, TUFPRENE, Asaprene (manufactured by Asahi  
Kasei Chemical Corporation), Sumitomo SBR  
(manufactured by Sumitomo Chemical Co., Ltd.), etc.,  
20 can be used.

In the present invention, these charge control  
agents, charge stabilizers and scattering stabilizers  
can be used singly or with two or more types combined.

Then, the effects of this embodiment will be  
25 explained.

According to this embodiment, of the first  
electrode area  $A_1$ , the area  $A_3$  adjacent to the second

electrode 4 is colored in substantially the same color as the color of the charged particles 9 (first color). Therefore, when the charged particles 9 are attracted to the first electrode 3, even if the  
5 density of the charged particles in the area  $A_3$  is lower (than the density of the charged particles in the rest of the first electrode area  $A_1$ ), the color seen from the gaps of charged particles is simply substantially the same color as the first color and  
10 the low density of charged particles is hardly visually recognized, which prevents the display quality from deteriorating.

(Second embodiment)

With reference to Figs. 4A, 4B, 5A and 5B,  
15 another embodiment of the present invention will be explained below.

An electrophoresis display apparatus according to this embodiment is provided, as shown in Figs. 4A and 4B, with a back substrate 1 and a transparent  
20 front substrate 2 arranged with a certain spacing in between, a support member 6 placed so as to keep the spacing between the substrates constant, a transparent insulating liquid 8 placed in a space surrounded by the back substrate 1, front substrate 2  
25 and support member 6, a plurality of colored charged particles 39 scattered in the insulating liquid, a colored first electrode 3 formed on the back

substrate 1, a second electrode 4 colored differently from the first electrode, a transparent insulating layer 41 placed on the first electrode 3 and second electrode 4 and a colored layer 35 placed on the back substrate 1. This colored layer 35 is placed in a gap between the first electrode 3 and second electrode 4 in a pixel.

Note that it is important that the colored layer 35 be placed so as to include at least the gap between the first electrode 3 and second electrode 4. However, the colored layer 35 shown in Figs. 4A and 4B does not limit the position and shape thereof. In addition to the position shown in Figs. 4A and 4B, it is also possible to place the colored layer 35 on the same plane as those of the first electrode 3 and second electrode 4 as shown in Fig. 5A or place the colored layer 35 on the plane including the first electrode 3 and second electrode 4 using white charged particles to display a white color and the color of the colored layer as shown in Fig. 5B. As preferred modes of this colored layer 35, it is preferable to place it so as to have a greater width than the gap between the first electrode 3 and second electrode 4, place it so as to include the plane overlapping the support member 6 within a plane horizontal to the back substrate 1 or form a film integral with the back substrate 1 so as to eliminate

the need for placing it positioned at the gap between the first electrode 3 and second electrode 4 as shown in Figs. 4A and 4B.

5           However, it is necessary to set the volume resistivity value so as to prevent the colored layer 35 from constituting an electrically short-circuit path between pixels. It is preferable to use a material for the colored layer having a volume resistivity value of  $1\text{E}+6 \Omega\text{cm}$  or greater.

10           Furthermore, it is necessary to set the color of the colored layer to a color capable of removing light of a wavelength region, which affects display contrast or brightness. For example, when the color of the charged particles 39 is substantially the same  
15 as the color of the second electrode 4, it is preferable that the color of the second electrode 4 be substantially the same as the color of the colored layer 35. Furthermore, to completely prevent unnecessary reflected light from between the  
20 electrodes, the color of the colored layer 35 is preferably black.

          The case where the color of the first electrode 3 is different from the color of the second electrode 4 has been described above, but note that this  
25 explanation does not limit the colors of the respective electrodes. For example, the second electrode 4 and first electrode 3 may also have the

same color. The colors of these electrodes should be selected and designed in consideration of the combination of colors, etc., of the charged particles 39 and insulating liquid 8 so that optimal brightness and contrast can be obtained for the display apparatus.

Furthermore, in Figs. 4A and 4B, only one type of the charged particles 39 is described, but two or more types can also be used. For example, there may also be a case where a plurality of types of particles having different particle diameters or different colors or different amounts of charge exist.

Furthermore, the color of the insulating liquid 8 is not limited to a transparent color. Any insulating liquid having nature of allowing light to transmit may be used and selected arbitrarily depending on its display color characteristic.

Moreover, the type of the insulating liquid 8 is not limited to one type in the entire display area.

That is, among pixel areas partitioned by the support members 36, there may be cases where different types of insulating liquid 8 are included. For example, it is also possible to form three consecutive areas as one set and use RGB or CMY as colors of the insulating liquids that fill the three areas and repeat this set cyclically in the display area.

Then, a display method for the electrophoresis display apparatus shown in Figs. 4A and 4B will be explained.

5 A display is performed by applying a voltage between the second electrode 4 and first electrode 3 and moving the charged particles 39 between the two electrodes. Here, a case where the first electrode 3 is colored in a highly reflective color and the second electrode 4 is colored in black will be  
10 explained. As shown in Fig. 4A, it is possible to concentrate charged particles 39 on the second electrode 4 and allow the first electrode 3 to reflect the incident light and thereby create a pixel in a bright display state. On the other hand, as  
15 shown in Fig. 4B, when the charged particles 39 are placed on the first electrode 3 and the reflective first electrode 3 is thereby covered with the charged particles 39. Thus, the incident light is reflected by the colored charged particles 39, which causes the  
20 color of the charged particles 39 to be the color displayed in the pixel. For example, when the charged particles 39 are colored in black, the display of the pixel in Fig. 4B becomes a black display.

25 Note that since the colored layer 35 is provided between the first electrode 3 and second electrode 4 and below the bottom face of the support

member 6, it is possible to effectively remove unnecessary reflected light from those areas. Thus, the image created by combining the bright display and black display shown in Figs. 4A and 4B becomes a display with high contrast.

Note that the components of the electrophoresis display apparatus according to this embodiment may be the same members as those described in the first embodiment.

As shown above, the effects of this embodiment include the ability to effectively prevent reflected light from the gap between the second electrode and first electrode, which is one cause of leakage of light, and at the same time the ability to remove leaked light from between pixels in this process of forming a colored layer. This makes it possible to achieve high contrast with a simple structure. Furthermore, as shown in Figs. 4A and 4B, the structure in which a colored layer is placed between both electrodes and the back substrate eliminates the need for fine positioning in manufacturing, which simplifies manufacturing. In this way, it is possible to achieve high yield in the process of the colored layer.

#### <Examples>

The present invention will be explained in more detail using Examples below.

(Example 1)

In this example, an electrophoresis display apparatus 51 having the structure shown in Figs. 1A and 1B will be created.

5           That is, a back substrate 1 and front substrate 2 are arranged with a predetermined spacing in between, a support member 6 is placed in the spacing between these substrates 1 and 2 so as to partition a pixel A and each pixel A is filled with an insulating  
10 liquid 8 and charged particles 9. Furthermore, each pixel A is provided with a first electrode 3 and second electrode 4 as shown in the figure. Then, a scattering layer 10 is formed on the entire substrate so as to cover the first electrode 3 and a colored  
15 layer 5 is placed in the areas  $A_2$  and  $A_3$  so as to cover the second electrode 4. Furthermore, the surfaces of this scattering layer 10, colored layer 5 and support member 6 are coated with a transparent insulating layer 11. Furthermore, a resin layer 42  
20 is formed on the surface of the front substrate 2 and an adhesion layer 12 is placed between this front substrate 2 and support member 6.

          In the present example, polystyrene particles (average particle diameter of 2.5  $\mu\text{m}$ ) colored in  
25 black with carbon black (CB, average particle diameter of 80 nm) which is inorganic pigment is used as the charged particles 9, the colored layer 5 is



also colored in black and the first electrode area  $A_1$   
(to be precise, the part  $A_1$  which is the first  
electrode area except the area  $A_3$  where the colored  
layer is placed) is designed to appear white through  
5 the function of the scattering layer 10.

Then, the method of manufacturing the  
electrophoresis display apparatus will be explained.

First, an aluminum film is formed to a  
thickness of 100 nm on the surface of the glass  
10 substrate 1 of 0.7 mm thick, which is then patterned  
to form the first electrode 3. Then, the  
polyurethane resin layer (scattering layer) 10  
whitened by mixing titanium oxide micro particles is  
formed so as to cover this first electrode 3.  
15 Furthermore, a dark-colored carbonized titanium film  
is formed in the area  $A_2$ , patterned into a linear  
shape through photolithography and dry etching to  
form the second electrode 4. The second electrode 4  
has a thickness of 50 nm and a line width of 12  $\mu\text{m}$ .

20 Furthermore, the aforementioned colored layer 5  
is formed. This colored layer 5 is linear-shaped so  
as to be placed not only in the area  $A_2$  where the  
second electrode 4 is formed but also in the area  
(see reference numeral  $A_3$ ) where the first electrode  
25 3 is formed. Furthermore, this colored layer 5 is  
formed by applying photosensitive resin (CFPR-BK738S  
manufactured by Tokyo Ohka Kogyo Co., Ltd.) in which

pigment is scattered to a film thickness of 1  $\mu\text{m}$  using a spinner and patterning it through exposure and wet developing. This colored layer 5 has a width of 22  $\mu\text{m}$  and the area  $A_3$  has a width of 5  $\mu\text{m}$ .

5           Then, by applying photosensitive epoxy resin (SU8 manufactured by MacDermid, Incorporated) followed by exposure and wet developing, the support member 6 is formed in the area  $A_2$  where the second electrode 4 is formed. The support member 6 has a  
10 height of 30  $\mu\text{m}$ , width of 12  $\mu\text{m}$  and spacing of 120  $\mu\text{m}$ . Then, the transparent resin layer 11 made of polyacrylate resin (optomer SS6699 manufactured by JSR Corporation) is formed so as to cover the inner surface of the cell.

15           Then, the UV-cured adhesion layer 12 is formed on the top surface (surface to which the substrate 2 is pasted) of the support member 6.

          Then, the concave section partitioned by the support member 6 is filled with a scattering liquid  
20 mixed with charged particles 9. The scattering liquid is prepared by mixing the charged particles of 1 weight ratio, isopar-H (manufactured by Exxon Corporation) of 100 weight ratio which is an aliphatic hydrocarbon solvent, zirconium octanate  
25 (Nikka octics zirconium, manufactured by Nihon Kagaku Sangyo Co., Ltd.) of 0.1 weight ratio, rosin ester (NEOTALL 125H, manufactured by Harima Chemicals,

Inc.) of 2.5 weight ratio and styrene butadiene copolymer (Asaprene 1205, manufactured by Asahi Kasei Chemicals Corporation) of 0.8 weight ratio and stirring it for one hour. Note that the charged  
5 polarity of the charged particles is negative.

Finally, the substrate 2 made of a polycarbonate film (100  $\mu\text{m}$  thick) is adhered to the support member 6 and UV-cured to create the electrophoresis display apparatus of the present  
10 invention.

Then, the display condition of the present example will be explained.

In the reflective electrophoresis display apparatus 51 created using the above-described method,  
15 when a voltage of the same polarity as the charged polarity of the charged particles 9 scattered in the insulating liquid 8 is applied to the first electrode 3, the charged particles 9 are attracted to the second electrode 4, which produces a white display.  
20 On the contrary, when a voltage of the polarity opposite to the charged polarity of the charged particles 9 scattered in the insulating liquid 8 is applied to the first electrode 3, the charged particles 9 are scattered over the first electrode 3  
25 and no white patch is found in the area  $A_3$  and good black brightness is confirmed.

(Example 2)

In the present example, the electrophoresis display apparatus 51 shown in Fig. 2 will be created. This has a structural difference from the electrophoresis display apparatus shown in Figs. 1A and 1B in that the colored layer 18 is placed only in the area  $A_3$  (without placing it in the area  $A_2$  where the second electrode 4 is placed) and the rest of the structure and the manufacturing method are the same.

Then, when the apparatus is driven in the same way as Example 1, the same display quality can be confirmed.

(Example 3)

In the present example, the electrophoresis display apparatus 51 shown in Fig. 3 will be created. That is, the second electrode 4 is placed not between the support member 6 and the back substrate 1 but outside the area where the support member 6 is placed and the colored layer 28 is placed so as to cover the second electrode 4 and stick out toward the first electrode 3. Note that the second electrode 4 has a width of 30  $\mu\text{m}$  and the colored layer 28 has a width of 35  $\mu\text{m}$ . The rest of the structure and the manufacturing method are the same as those in Example 1.

When the apparatus is driven in the same way as Example 1, the same display quality can be confirmed. (Example 4)

In the present example, the electrophoresis display apparatus shown in Figs. 4A and 4B will be explained.

Suppose the display apparatus to be created has  
5 200×200 pixels and one pixel is a square of 100  $\mu\text{m}$   
per side. Each pixel is surrounded on all four sides  
by a transparent support member 6. The support  
member 6 has a height of 25  $\mu\text{m}$  and this distance  
corresponds to the cell gap. The support member 6  
10 has a width of 5  $\mu\text{m}$  and the area occupied by the  
support member 6 within the substrate plane  
corresponds to the non-aperture area. Furthermore, a  
black colored layer 35 is formed as a film integral  
with the back substrate within a range of the display  
15 area. Furthermore, a first electrode 3 and a second  
electrode 4 are placed on the colored layer 35 on the  
back substrate 1 and suppose a gap  $g$  (spacing  
indicated by dotted lines in the figure) between the  
two electrodes is 10  $\mu\text{m}$ . Suppose the area ratio  
20 within the pixel of the first electrode 3 and second  
electrode 4 is 7:3. To provide the first electrode 3  
with a light absorption characteristic, a transparent  
material is used. That is, light incident on the  
second electrode 4 passes through the transparent  
25 second electrode 4 and is absorbed by the colored  
layer 35 placed beneath the second electrode 4. On  
the other hand, a highly reflective metal is used for

the first electrode 3 so as to provide it with a light reflecting characteristic and a fine concavo-convexo structure is provided on the electrode surface though not shown. This concavo-convexo structure is designed so as to scatter reflected light. Furthermore, in order to prevent charged particles 39 and an insulating liquid 8 from provoking electrode reaction or charge injection, etc., causing the behavior of the charged particles 39 to change to substantially an instable condition with time, a transparent thin film insulating layer 41 is laminated on the second electrode 4 and first electrode 3. Furthermore, the black charged particles 39 of a predetermined density and transparent insulating liquid 8 are stably enclosed in a closed space surrounded by the back substrate 1, front substrate 2 and support member 6.

Then, the method of manufacturing the electrophoresis display apparatus according to the present example will be explained below.

As the back substrate 1 shown at the bottom in the figure which is a substrate, a 150  $\mu\text{m}$  PET film is used, a photosensitive resin material (CFPR BK, manufactured by Tokyo Ohka Kogyo Co., Ltd.) containing carbon is applied thereto to a thickness of 3  $\mu\text{m}$  to form the colored layer 35. Then, the black resin material other than the display area is

removed using photolithography. Then, the second electrode 3 is patterned using a transparent electrode ITO. In the area where the first electrode 3 is placed, a micro concavo-convexo structure is formed (not shown) using resin beforehand, the first electrode 3 is patterned thereon using Al to form the reflective first electrode 3. Next, the insulating layer 41 is formed in the display area using transparent acrylic-based resin (optomer, manufactured by JSR Corporation) so as to cover the second electrode 4 and first electrode 3. Then, the support member 6 is formed using a thick film photoresist (THB, manufactured by JSR Corporation) through photolithography. Then, though not shown, polycarbonate resin is applied to the support member 6 and insulating layer 41 as a thin surface coating layer. The thickness of the surface coat layer is approximately 100 nm. Applying this surface coat layer has the effect of strengthening the support member 6 with a high aspect ratio against shock. Then, the space partitioned by the support member 6 on the back substrate 1 is filled with the transparent insulating liquid 8 and a plurality of black charged particles 39 in such a way that the density of charged particles 39 of all pixels becomes uniform. As the insulating liquid 8, isopar (manufactured by Exxon) is used and black charged

particles 39 containing carbon having an average particle diameter of 3  $\mu\text{m}$  are scattered therein and used. Furthermore, isopar (manufactured by Exxon) is used for the insulating liquid 8 and imide succinate is included as a charge control agent. After filling, the top end of the support member 6 and the front substrate 2 are adhered together and the space portioned by the support member 6 is sealed with the insulating liquid 8 and charged particles 39. After the sealing, the front substrate 2 and back substrate 1 are adhered together around the substrate using an adhesive (not shown).

Then, the display condition in the present example will be explained.

In the reflective electrophoresis display apparatus 51 created using the above-described method, when a voltage of the same polarity as the charged polarity of the charged particles 39 scattered into the insulating liquid 8 is applied to the first electrode 3, the charged particles 39 are attracted to the second electrode 4, producing a bright display. On the contrary, when a voltage of the polarity opposite to the charged polarity of the charged particles 39 scattered into the insulating liquid 8 is applied to the first electrode 3, the charged particles 39 are attracted to the first electrode 3, producing a black display, the same black color as



the color of the charged particles 39. When a bright display or dark display is performed in this way, the light leaking from the gap between the first electrode 3 and second electrode 4 and from the support member 6 is mostly intercepted by the colored layer 35, making it possible to obtain a display with high contrast. Moreover, since this is a process capable of forming the light-reflecting layer 35 without any control over positioning in a narrow gap of only 10  $\mu\text{m}$  between the first electrode 3 and second electrode 4, it is possible to drastically improve yield.

(Example 5)

In the present example, the electrophoresis display apparatus shown in Fig. 6 will be explained.

Suppose the display apparatus to be created has 200 $\times$ 200 pixels and one pixel is a square of 100  $\mu\text{m}$  per side. Each pixel is surrounded by a black support member 6. The support member 6 has a height of 10  $\mu\text{m}$  and this distance corresponds to the cell gap. The support member 6 has a width of 5  $\mu\text{m}$ .

The gap ( $g$  in the figure) between the first electrode 3 and second electrode 4 placed on the back substrate 1 is set to 5  $\mu\text{m}$  and the colored layer 35 having a width ( $s$  in the figure) of 20  $\mu\text{m}$  is provided on the back substrate 1 in such a way as to include the gap. Suppose the area ratio within the pixel of

the first electrode 3 and second electrode 4 is 7:3. That is, the width  $s$  of the colored layer 35 is set sufficiently wide compared to the distance  $g$  between the electrodes. This colored layer 35 is patterned  
5 by applying a printing method to resin containing carbon. Furthermore, the second electrode 4 and first electrode are made of the same material. Furthermore, in order to prevent charged particles 39 and an insulating liquid 8 from provoking electrode  
10 reaction or charge injection, etc., causing the behavior of the charged particles 39 to change to substantially an instable condition with time, a transparent thin film insulating layer 41 is laminated on the first electrode 3 and second  
15 electrode 4. Furthermore, a transparent insulating liquid 8 in which white charged particles 39-1 and black charged particles 39-2 of a predetermined density are scattered is stably enclosed in a closed space surrounded by the back substrate 1, front  
20 substrate 2 and support member 6. The white charged particles 39-1 and black charged particles 39-2 are charged with different polarities in the insulating liquid 8.

Then, the method of manufacturing the  
25 electrophoresis display apparatus according to the present example will be explained below.

The colored layer 35 is patterned on the back

substrate 1 which is the substrate at the bottom in the figure using an SUS substrate having a thickness of 0.5 mm and a black resin layer containing carbon thereon according to a printing method. The width  $s$  of the colored layer at this time is set to 20  $\mu\text{m}$ . The first electrode 3 and second electrode 4 are formed thereon simultaneously using Al. The gap  $g$  between the two electrodes is 5  $\mu\text{m}$  and the electrodes are placed so as to be superimposed on the already formed colored layer 35. Since the width  $s$  of the colored layer is sufficiently large compared to the gap  $g$  between the electrodes, the positioning process when the first electrode 3 and second electrode 4 are patterned is extremely easy. Then, the transparent insulating layer 41 is coated so as to cover the first electrode 3 and second electrode 4. Then, the support member 6 is formed using photosensitive resin containing carbon around the pixel. Then, the space partitioned by the support member 6 is filled with the insulating liquid 8 in which white charged particles 39 and black charged particles 39-2 are scattered. Titanium oxide having a particle diameter of 1 to 2  $\mu\text{m}$  is used for the white charged particles 39-1 and polystyrene-polystyrene methacrylate copolymer resin containing carbon black having a particle diameter of 0.1 to 0.3  $\mu\text{m}$  is used for the black charged particles 39-2. Furthermore, isopar

(Exxon) is used for the insulating liquid 8 and imide succinate is included therein as a charge control agent. Then, using the front substrate 2, the closed space surrounded by the back substrate 1, front  
5 substrate 2 and support member 6 is sealed with the insulating liquid 8 in which the white charged particles 39-1 and black charged particles 39-2 are scattered.

In the reflective electrophoresis display  
10 apparatus 51 created using the above described method, when a voltage of the same polarity as the charged polarity of the white charged particles 39-1 scattered into the insulating liquid 8 is applied to the first electrode 3, the white charged particles  
15 39-1 are attracted to the second electrode 4 and the black charged particles are attracted to the first electrode 3, and therefore approximately 70% of light incident on the pixel is absorbed by the black charged particles 39-2, producing a dark display. On  
20 the contrary, when a voltage of the polarity opposite to the charged polarity of the white charged particles 39-1 scattered in the insulating liquid 8 is applied to the first electrode 3, the black charged particles 39-2 are attracted to the second  
25 electrode 4 and the white charged particles 39-1 are attracted to the first electrode 3, and therefore the light incident on the pixel is reflected by the Al

electrode and further scattered by the white charged particles 39-1, thus producing a white bright display.

In this way, unnecessary reflected light which leaks from the gap between the first electrode 3 and second electrode 4 can be mostly intercepted by the colored layer 35, and therefore it is possible to reduce the black reflective factor and obtain a display with high contrast. Moreover, this is a process capable of forming a light reflecting layer in a narrow gap of only 5  $\mu\text{m}$  between the first electrode 3 and second electrode 4 without any need for difficult positioning control, and therefore it is possible to drastically improve yield.

(Example 6)

In the present example, the electrophoresis display apparatus shown in Fig. 7 will be explained.

Suppose the display apparatus to be created has 200 $\times$ 200 pixels and one pixel is a square of 100  $\mu\text{m}$  per side. Each pixel is surrounded by a second electrode 4 also serving as a support member 6. The second electrode 4 has a height of 20  $\mu\text{m}$  and this distance corresponds to the cell gap. Furthermore, the second electrode 4 has a width of 5  $\mu\text{m}$ .

A colored layer 35 is placed on a back substrate 1 and a first electrode 3 is connected to a TFT (abbreviation of Thin Film Transistor) which is a switching element 30 through a through hole provided

in the central area of the pixel. Furthermore, in order to prevent charged particles 39 and an insulating liquid 8 from provoking electrode reaction or charge injection, etc., causing the behavior of the charged particles 39 to change to substantially an instable condition with time, an insulating color filter 41 is laminated on the first electrode 3 and second electrode 4. Furthermore, a transparent insulating liquid 8 in which black charged particles 39 of a predetermined density are scattered is stably enclosed in a closed space surrounded by the back substrate 1, front substrate 2 and support member 6.

Then, the method of manufacturing the electrophoresis display apparatus according to the present example will be explained below.

A glass substrate having a thickness of 0.8 mm is used for the back substrate 1, which is the lower substrate in the figure and an a-Si TFT is formed thereon. The colored layer 35 is patterned on the a-Si TFT using photosensitive resin containing carbon. A convex structure is formed on the area peripheral to the pixel and the first electrode 3 and second electrode 4 are formed simultaneously using Al. The gap  $g$  between the two electrodes is set to 5  $\mu\text{m}$  and the electrodes are superimposed on the colored layer 35 in which the gap is formed beforehand. Then, the color filter, which is the insulating layer 41, is

patterned so as to cover the first electrode 3 and second electrode 4. Using three adjacent pixels as one set, a CMY color filter is patterned on the respective three pixels. Then, the space partitioned by the second electrode 4, which also serves as the support member, is filled with the insulating liquid 8 in which black charged particles 39 are scattered. Polystyrene-polystyrene methacrylate copolymer resin containing carbon black having a particle diameter of 1 to 3  $\mu\text{m}$  is used for the black charged particles 39-2. Furthermore, isopar (Exxon) is used for the insulating liquid 8 and imide succinate is included therein as a charge control agent. Then, using the front substrate 2, the closed space surrounded by the back substrate 1, front substrate 2 and first electrode 3 which also serves as the support member is sealed with the insulating liquid 8 in which the black charged particles 3 are scattered.

In the reflective electrophoresis display apparatus 51 created using the above-described method, when a voltage of the same polarity as the charged polarity of the charged particles 9 scattered in the insulating liquid 8 is applied to the first electrode 3, the charged particles 9 are attracted to the second electrode 4, producing a bright display. For example, when the color filter placed in this pixel is yellow (Y), the yellow color is displayed. On the

contrary, when a voltage of the polarity opposite to the charged polarity of the charged particles 39 scattered in the insulating liquid 8 is applied to the first electrode 3, the charged particles 39 are  
5 attracted to the first electrode 3, producing a dark display in the same black color as the color of the charged particles.

In this way, unnecessary reflected light which leaks from the gap between the first electrode 3 and  
10 second electrode 4 can be mostly intercepted by the colored layer 35, and therefore it is possible to reduce the black reflective factor and obtain a display with high contrast. Moreover, this is a process capable of forming the light-reflecting layer  
15 35 in a narrow gap of only 5  $\mu\text{m}$  between the first electrode 3 and second electrode 4 without any need for difficult positioning control, and therefore it is possible to drastically improve yield. Furthermore, it is possible to suppress a mixture of  
20 leaked light from the adjacent pixels and thereby provide a bright color display.

As shown above, the moving particle type display apparatus according to the present invention can prevent unnecessary reflected light from within  
25 the pixels. More specifically, of the first electrode area, the area adjacent to the second electrode is colored in substantially the same color



as the color (first color) of charged particles.  
Therefore, when the charged particles are attracted  
to the first electrode, even if the density of the  
charged particles in the area is low (compared to the  
5 density of charged particles in the rest of the first  
electrode area), the color seen from the gaps of the  
charged particles is only substantially the same  
color as the first color and the low density of the  
charged particles is hardly visually recognized and  
10 it is possible to thereby prevent the display quality  
from deteriorating. Furthermore, it is possible to  
suppress leaked light from between the electrodes and  
thereby improve the display contrast. Furthermore,  
depending on the display mode, there is no  
15 interference of leaked light from the adjacent pixels,  
which allows a bright display. Furthermore, this  
colored layer can be placed through a simple process,  
and therefore it is possible to improve the yield of  
manufacturing and reduce cost because there are fewer  
20 restrictions on the manufacturing apparatus and  
materials.

## CLAIMS

1. A reflective display apparatus that creates a display by moving particles, comprising:
- a front substrate and a back substrate;
  - 5 a plurality of charged particles sandwiched between said front substrate and back substrate;
  - a first electrode and a second electrode placed on said back substrate;
  - a support member provided to keep a distance
  - 10 between said front substrate and back substrate; and
  - a colored area provided on said back substrate, wherein reflecting means is provided in a space partitioned by said support member and said colored area is placed in such a way that the surface of
  - 15 projection on the back substrate of said second electrode and the surface of projection on the back substrate of said colored zone at least contact with each other.
- 20 2. The reflective display apparatus according to claim 1, wherein said colored area is colored in substantially the same color as that of said charged particles and the area other than said colored area is colored in a second color which is different from
- 25 the color of the charged particles.

3. The reflective display apparatus according

to claim 1, wherein said colored area is a light  
absorbing layer, a gap is provided between said first  
electrode and second electrode within the back  
substrate and the colored area is placed on the back  
5 substrate so as to overlap at least with the gap.

4. The reflective display apparatus according  
to claim 1, wherein said support member is placed so  
as to partition the pixel.  
10

5. The reflective display apparatus according  
to claim 1, wherein said second electrode is provided  
on said support member.

15 6. The reflective display apparatus according  
to claim 1, wherein said second electrode is placed  
between said support member and said back substrate.

7. The reflective display apparatus according  
20 to claim 1, wherein an insulating liquid is further  
provided in the gap between said front substrate and  
back substrate.

8. The reflective display apparatus according  
25 to claim 1, wherein said colored area is a light  
absorbing layer and includes a plane overlapping with  
said support member within a plane horizontal to said

back substrate.

9. The reflective display apparatus according to claim 1, wherein said colored area is a light  
5 absorbing layer and provided on one side of the display area of said display apparatus.

10. The reflective display apparatus according to claim 1, wherein said colored area is a light  
10 absorbing layer and placed between said first electrode and second electrode, and said back substrate.

11. The reflective display apparatus according to claim 1, wherein said reflecting means is said  
15 plurality of types of charged particles.

12. The reflective display apparatus according to claim 1, wherein said reflecting means is a light  
20 reflecting layer provided on said back substrate.

13. The reflective display apparatus according to claim 12, wherein said light reflecting layer includes at least one of said first electrode or  
25 second electrode.

14. The reflective display apparatus according

to claim 12, wherein the surface of said light reflecting layer is provided with a concavo-convexo structure.

5           15. An electrophoresis display apparatus comprising:

          a first substrate and second substrate arranged with a predetermined gap in between;

          an insulating liquid and a plurality of charged  
10 particles enclosed in the gap between these substrates;

          a first electrode placed along said first substrate over a relatively wide area of a pixel; and

          a second electrode between which and said first  
15 electrode a voltage is applied, said electrophoresis display apparatus carrying out a display by applying a voltage to these electrodes and moving said charged particles,

          wherein said charged particles are colored in a  
20 first color,

          at least a portion of the area where said first electrode is placed in which the density of said charged particles cannot be kept high is colored in substantially the same color as said first color,

25           at least a portion of the area where said first electrode is placed in which the density of said charged particles can be kept high is colored in a

second color,

when said charged particles are placed so as to cover said first electrode, said first color is visually recognized, and

- 5        when said charged particles are attracted to said second electrode and accumulated, said second color is visually recognized.

## ABSTRACT

There is a demand for preventing display quality of a display apparatus from deteriorating. When charged particles 4 are attracted to a first electrode 5, the distribution density may not become uniform over the entire area A1 and only the distribution density in the periphery of the first electrode 5 (see reference numeral A3) may be locally reduced. The present invention places a colored layer 8 having the same color as the color of charged particles in this area A3. Therefore, even if the distribution density is low, the low density is hardly visually recognized, making it possible to prevent the display quality from deteriorating.